DEFENCE DÉFENSE

Evaluation of Iridium Satellite Phone Voice Services for Military Applications

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Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 1999-086
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ABSTRACT

The Iridium system is designed to provide global personal communications via an interconnected constellation of Low Earth Orbit (LEO) satellites communicating directly with handheld terminals. The system provides communications to all parts of the globe, including the polar regions. This document describes the DREO evaluation of the Iridium voice service under a number of different scenarios. Also included is an overview of the general features and operation of the satellite phone.

RÉSUMÉ

Le système Iridium a été développé pour fournir la communication personnelle et globale. Le système s'agit d'une constellation interconnectée de satellites en orbite basse terrestre qui fonctionne directement avec les terminaux portatifs. Le système Iridium permet la communication à n'importe quel endroit au monde, y compris les régiones polaires. Ce document décrit l'évaluation du service vocal sous plusieurs scénarios par le Centre de Recherche pour la Défense à Ottawa (CRDO). Un sommaire général des caractéristiques et de l'opération de l'appareil téléphonique Iridium est aussi inclus.

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EXECUTIVE SUMMARY

The Iridium system is designed to provide global personal communications via an interconnected constellation of Low Earth Orbit (LEO) satellites communicating directly with handheld terminals. The system provides continuous communications to all parts of the globe, including the polar regions and is the only system capable of providing handset to handset communication without a ground-based hub. The Iridium system is one of a number of satellite based personal communications systems designed to overcome the distance limitations of terrestrial based systems and provide a truly global capability.

The Military Satellite Communications (MSC) Group at Defence Research Establishment Ottawa (DREO) purchased three sets of Iridium Satellite Series 9500/9501 phones and pagers. Since March 1999, the MSC group has been carrying out voice service trials to evaluate the voice service and subsequently the potential for use of Iridium by the military. Reliability and quality of the voice service are key components of interest.

The Iridium voice service was evaluated under a number of conditions, between both male and female speakers, in English and French, to a number of different terminal devices. The users were always aware that a vocoder was being used. However, after some experience using the system, and good conditions, speaker recognition was possible. Understanding ranged from near PSTN quality to poor, with an acceptable rating for most of the calls. The average 4 minutes of usable conversation times would probably be acceptable for most applications. The greatest success was obtained when the Iridium phones were used away from buildings or other obstructions. The most acceptable calls were between two Iridium phones or between Iridium and PSTN phones. Calls made to terrestrial cellular phones were of lower voice quality and connections were less reliable.

The user acceptance and ease of use of the system would probably depend on past experience of the user and perceived expectation from the service. If the user expects a terrestrial cellular equivalent, there will be a disappointment in terms of where the system can be used (i.e. inside buildings), quality of the voice, and call length. However, if the user considers the system as a replacement of terrestrial HF, a replacement of current SatCom service, or a new service where none now exists (i.e. polar and remote locations), the Iridium system is a large step forward.

Tom, C., Wagner, L., Evaluation of Iridium Satellite Phones Voice Services for Military Applications, Defence Research Establishment Ottawa, DREO TM 1999-086, September 1999

SOMMAIRE

Le système Iridium est conçu pour permettre des communications personnelles partout dans le monde grâce à une constellation de satellites sur orbite terrestre basse interconnectés qui communiquent directement avec des terminaux à main. Le système assure des communications ininterrompues dans toutes les parties du monde, y compris les régions polaires; il est également le seul système qui permet la communication entre combinés sans l'intermédiaire d'une station pivot au sol. Le système Iridium est un des systèmes de communications personnelles par satellite qui ont été conçus pour dépasser les limites de portée des systèmes de Terre et qui peuvent vraiment fonctionner partout dans le monde.

Le Groupe des télécommunications militaires par satellite (MSC) du Centre de recherches pour la Défense Ottawa (CRDO) a acheté trois ensembles de postes téléphoniques et de récepteurs de téléappel de la série Satellite 9500/9501 d'Iridum. Depuis mars 1999, le groupe MSC effectue des essais en vue d'évaluer en un premier temps le service téléphonique et ensuite l'utilisation possible des appareils Iridium par les Forces canadiennes. La fiabilité et la qualité des communications vocales sont les principaux éléments à l'étude.

Le service téléphonique d'Iridium a été évalué dans diverses conditions, par des hommes et par des femmes parlant anglais ou français et à l'aide de terminaux de divers types. Les utilisateurs savaient toujours qu'un codeur vocal était utilisé. Cependant, après avoir utilisé le système pendant un certain temps, les utilisateurs pouvaient reconnaître leur interlocuteur quand les conditions étaient bonnes. Le degré de compréhension se situait entre celui offert par le RTPC et un degré médiocre; la qualité étant acceptable pour la majorité des appels. La durée moyenne de conversation utile de quatre minutes suffirait probablement pour la majorité des applications. Le taux de succès était le plus élevé lorsque les téléphones Iridium étaient utilisés loin des immeubles ou d'autres obstacles. La qualité la plus acceptable était obtenue lorsque les communications avaient lieu entre deux téléphones Iridium, ou entre un téléphone Iridium et un téléphone du RTPC. Les communications établies avec les téléphones cellulaires de Terre étaient de plus mauvaise qualité, et la connexion était moins fiable.

L'acceptation par l'utilisateur et la facilité d'utilisation du système dépendront probablement de l'expérience antérieure de l'utilisateur et de ses attentes envers le service. Si l'utilisateur s'attend à obtenir un service de qualité équivalente à celui d'un téléphone cellulaire de Terre, il sera déçu quant à l'endroit où celui-ci peut être utilisé (c.-à-d. à l'intérieur des immeubles), à la qualité de la voix et à la durée des appels. Cependant, si l'utilisateur considère ce système comme un remplacement pour les systèmes HF de Terre et le service de télécommunications par satellite actuel, ou comme un nouveau service dans les endroits où il n'en existe aucun (c.-à-d. dans les régions polaires et éloignées), le système Iridium représente une amélioration notable.

Tom, C., Wagner, L., Évaluation du service téléphonique Iridium pour l'utilisation possible par les Forces Canadiennes , Le Centre de recherches pour la défense Ottawa, DREO TM 1999-086, septembre 1999 (en anglais)

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LIST OF SYMBOLS AND ABBREVIATIONS

AMPS – Advanced Mobile Phone System
bps – bits per second
C3I – Control, Communications and Information
CDMA – Code Division Multiple Access
DAR – Director Air Requirements
DREO – Defence Research Establishment Ottawa
FDMA – Frequency Division Multiple Access
GMPCS – Global Mobile Personal Communications Systems
GSM – Global System for Mobile Communications
HF – High Frequency
LEO – Low Earth Orbit
MHz – Mega Hertz
MRT – Modified Rhyme Test
MSC – Military Satellite Communications
PIN – Private Identification Number
PSTN – Public Service Telephone Network
QPSK – Quadrature Phase Shift Keying
SatCom – Satellite Communication
SIM – Subscriber Identity Module
STK – Satellite Tool Kit
TDMA – Time Division Multiple Access
TP – Technical Panel
TTCP – The Technical Cooperation Panel

1 INTRODUCTION

1.1 General

Over the past decade there has been a phenomenal growth in the demand for terrestrial based cellular personal communications services. The current estimate is that by the year 2000 there will be between 300 to 350 million subscribers worldwide. This service is mostly centered around populated areas in developed countries, but expansion of the service to less populated areas and third world countries is progressing rapidly. Terrestrial based cellular is a line-of-sight technology. That is, the subscriber must have a line-of-sight to the base transceiver stations. This distance is usually a few kilometers in high density areas to a few tens of kilometers in less dense areas. Therefore, to expand the reach capability of this technology, base transceiver stations must be constructed with linkages back to central hubs. Satellite based personal communications systems were designed to overcome the distance limitations of terrestrial based systems and provide a truly global capability.

The advantage of satellite based cellular services is that the functional equivalent of the base stations is provided by a constellation of orbiting satellites. Each satellite projects a number of beams, or cells, on the surface of the earth, each typically many hundreds kilometers in diameter. The design of the satellite and satellite constellation is such that at least one satellite is always in view of the handset. The functioning of a satellite-based system is inverted to that of a terrestrial based system. Because the satellite is moving at a much higher speed then the user, the user is effectively stationary and the satellite base stations move. The disadvantage of satellite based service is the greater line-of-sight distance between the user and the base station and consequently the need for much higher link margins. Therefore, services to the interior of buildings and areas obstructed by terrain or foliage may be degraded.

1.2 Iridium System

The Iridium system is designed to provide global personal communications via an interconnected constellation of Low Earth Orbit (LEO) satellites communicating directly with handheld terminals. The system provides communications to all parts of the globe, including the polar regions. The Iridium constellation consists of 66 satellites in 6 near polar orbits of 11 satellites at an altitude of 780 km as shown in Figure 1. Each satellite projects 48 beams of approximately 70 km diameter each on the surface of the earth, with a total footprint of approximately 4,700 km diameter. The constellation was selected to provide overlapping footprints at the equator to support continuous coverage and transparent hand-off between satellites. As a consequence, the overlap increases as the satellites approach the poles.

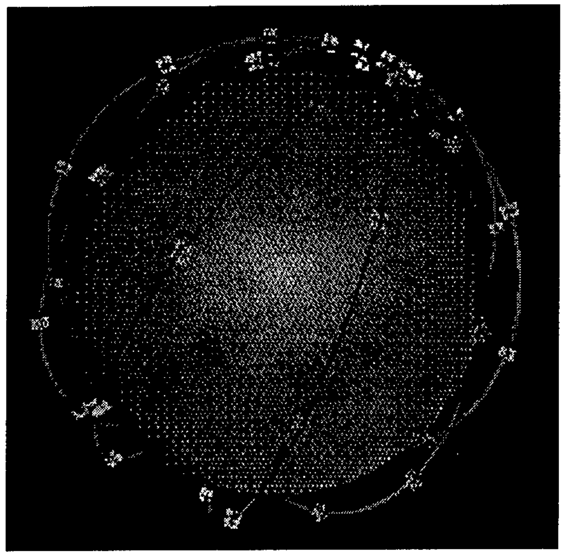

Figure 1 Iridium Constellation (www.iridium.com)

The Iridium satellite is a processing satellite based upon the Global System for Mobile Communications (GSM) technology. This allows the handset to directly communicate to the satellite and to pass data independent of terrestrial gateways. Of the projected new systems, Iridium is the only system that provides communications between two satellite handsets without being downlinked through a terrestrial gateway. The Iridium system uses 1616 MHz to 1626.5 MHz to provide communications between the handset and satellite for telephone and messaging services. The links use frequency division multiple access (FDMA) and time division multiple access (TDMA) to separate users and uplink and downlink communications. The waveform employs quadrature phase shift keying (QPSK). Each satellite is linked to four other satellites (one behind, one ahead, and one in each adjacent orbit) by four separate inter-satellite links. This allows communications to the Iridium handsets to be handed off between satellites as the satellites pass overhead and allow communications to be routed within the satellite constellation without downlinking to a ground station. Figure 2 is an artist's rendition of the Iridium satellite. Figure 3 is an actual photograph of seven Iridium spacecraft attached to a Russian Proton launcher.

The first four satellites were launched into orbit in May 1997, with the total constellation of 66 satellites plus spares being completed in May 1998. A total of 72 satellites were put into orbit with 15 launches over a 12-month period. Initial voice service commenced in November 1998 which was followed by paging service in March 1999. Data service at 2400 bps is expected in the fall of 1999.

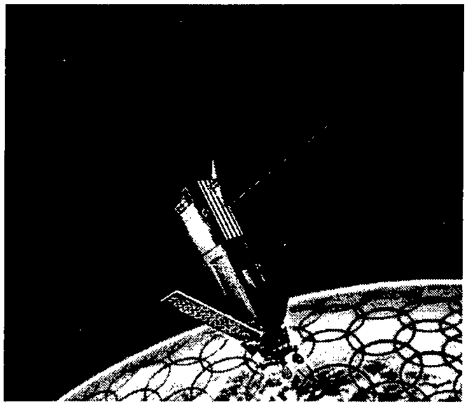

Figure 2 Artist's Rendition of an Iridium Satellite (www.flatoday.com)

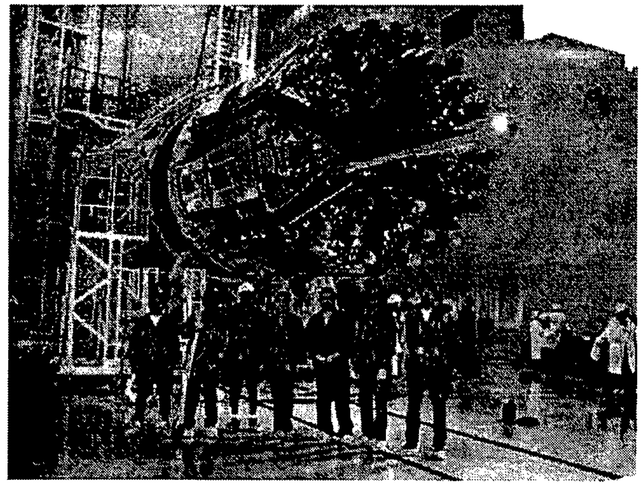

Figure 3 Seven Iridium Satellites on a Proton Launcher (www.flatoday.com)

Pictures of the Motorola and Kyocera Iridium phones are shown in Figure 4, the Motorola phone is on the left with the cellular cassette and antenna installed. They are comparable in size and weight to existing medium sized cellular phones. The current price is around $2,500 Cdn with usage fees from $2.50 Cdn per minute for domestic calls to $4.50 Cdn per minute for international calls. Calls made to non-Iridium phones may also have "tail" circuit costs. Depending on the batteries used, the phones are can communicate continuously from 2 to 6 hours or standby from 16 to 60 hours.

Figure 4 Motorola and Kyocera Iridium Phones (www.infosat.com)

1.3 Background

The Military Satellite Communications (MSC) Group at Defence Research Establishment Ottawa (DREO) purchased three sets of Iridium Satellite Series 9500/9501 phones and pagers. Since March 1999, the MSC group has been carrying out voice service trials to evaluate the voice service and subsequently the potential for use of Iridium by the military. Reliability and quality of the voice service are key components of interest. Messaging services to the phones and pagers are also being examined. Important elements of the messaging service to be investigated include efficiency in delivery and error performance. Although of great interest, the 2400 bps data service offered by Iridium is not yet available and thus is not considered in this technical memorandum. Evaluation of Iridium's paging service is documented in a separate technical memorandum [4].

The MSC group is also participating in The Technical Cooperation Program (TTCP) Command, Control, Communications and Information (C3I) Group, Technical Panel (TP) 6 Workshop on Global Mobile Personal Communications Systems (GMPCS) to examine the Iridium system for military applications. Other members participating in the workshop consist of Australia, United Kingdom, and United States. The TTCP forum provides the opportunity for the MSC group to share technical knowledge as well as coordinate national efforts for evaluating the Iridium service. The work presented in the Technical Memorandum has been briefed to the TTCP workshop. In general, the results obtained in the DREO evaluation agree with other nations' findings.

1.4 Outline of Technical Memorandum

This technical memorandum describes the DREO evaluation of the Iridium voice service. An overview of the general features and operation of the satellite phone is given in Section 2.0. Section 3.0 describes the test procedure used in the evaluation and presents the different scenarios tested. Results and general observations are compiled in Section 4.0. Section 4.0 also identifies any issues which were not resolved during the evaluation period and where applicable provides proposals for further testing. A preliminary assessment of the utility of the Iridium voice service for military use is made in Section 4.0. Section 5.0 consists of general conclusions of the evaluation.

2 SATELLITE PHONE FEATURES AND OPERATION

2.1 General Description

The front of the Motorola Iridium phone is shown in Figure 5. It contains the earpiece, display, special keys, alphanumeric keypad, and microphone. On the left side are the volume keys and on the right is the subscriber identity module (SIM) card eject button. Underneath is the SIM card port and accessory connector. On the back is the battery cover and antenna. The SIM card is a smart card that contains the phone number, service details, and memory for storing phone book entries and messages. The phone has very limited functionality without the SIM card, and it is not possible to make or receive phone calls. The phones will also support the Global System for Mobile Communications (GSM) SIM cards, but you will not have access to certain specific features that are unique to the Iridium system. In order for the phone to operate in satellite mode the satellite antenna must be attached and rotated to an upright position.

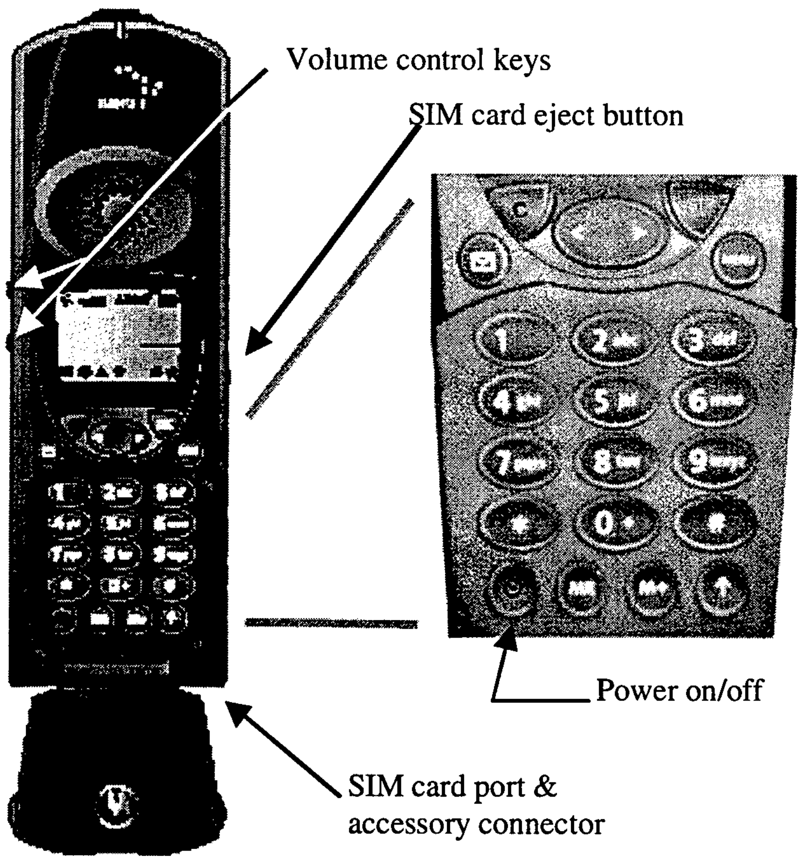

Figure 5 Motorola Iridium Phone

2.2 Getting Started

The following is a brief description on the use of the Motorola Iridium phone extracted from the user's guide. For more detailed instruction or to use the more advanced features of the phone, the user is directed to Motorola Iridium 9500 Portable Phone User's Guide [5]. To start using the phone in satellite mode insure that the battery, the satellite antenna, and the SIM card are installed. You should be in a position with a clear line of sight to most of the horizon. The phone may work inside buildings near exterior windows or outside in areas that are obstructed by terrain or foliage, but the most consistently successful results are in areas with good view of the sky. Rotate the satellite antenna to one of the détente positions and insure the antenna has a clear view of the sky. Open the keypad cover and press and hold the power button, the red button in the lower left corner. You will then be prompted for the SIM private identification number (PIN). This is a unique number that is stored in the SIM card and provides a security capability if the card is lost or stolen. The number can be changed by the user, see the user's guide for instructions. The phone will then go into satellite search mode to attempt to register on the Iridium system. When the phone has registered on the Iridium system it indicates that is ready to make or receive calls and will display the signal strength indicator (one to five bars) for a few seconds. If the phone is unable to register with the system it is usually caused by obstruction of the signal due to buildings, terrain, foliage, or satellites being too low on the horizon. The last problem can usually be solved by waiting a minute, as the orientation of the satellite constellation will have changed to a more favorable alignment. The first three problems can usually be rectified by moving to a better location.

To make a call press and hold the "0+" button. In a few seconds the international dialing prefix "+" will appear on the display. Enter the country code and phone number and press the "OK" button. The country code for North America is "1", the country code for the Iridium system is "8816" or "8817". The phone will attempt to complete the call and will display to the user the status of the call. When the call connects a timer indicating the length of time of the call will be displayed. To end the call press the "OK" button, the "C" button, or close the keypad cover. The duration of the call will be displayed for a few seconds

2.3 Accessories

A number of accessories are available for both the Kyocera and Motorola Iridium phones. The Motorola accessories that DREO has purchased are:

- High capacity battery.
- External antennas - magnetic mount for vehicles and fixed mount.
- Terrestrial cellular cartridges – GSM and CDMA/AMPS
- Portable dock for fixed locations.
- Desktop battery charger

2.4 Advanced Features

The Motorola Iridium phone supports a number of advanced features. A brief description of the satellite features is presented here. A more detailed description is available in the user's guide.

- Automatic redial
- Call a number embedded in a message
- Phone book – the phone contains a phone book that can be used to store names and telephone numbers. This information can be stored in the phone or on the SIM card.
- Personal mailbox – the phone can receive voicemail and facsimile notification, numeric messages, and text messages.
- Redial last number.
- Unanswered call message.
- Call waiting – the system will notify the phone of an incoming call when there is an existing call in progress.
- Call holding – calls can be placed on hold to receive a new call or make a new call.
- Call muting.

3 TEST PROCEDURE

3.1 Objective

The objective of the tests carried out at DREO was to become familiar with the features of the Iridium voice service and to evaluate the voice service capabilities over different communications links. A second critical objective was to determine service reliability.

3.2 Test Method

The method for testing the Iridium voice service was to establish calls between a Motorola Iridium phone and another device. Other devices include public service telephone network (PSTN), digital cellular phone (Qualcomm 2700), and other Motorola Iridium phones. For each call established, the information recorded includes call setup time, call duration, whether the call is dropped, whether satellite handover is noticeable to the user, environmental and operating conditions, and overall quality (e.g. signal strength).

For evaluation of voice intelligibility, an abbreviated version of the Modified Rhyme Test (MRT) was carried out. The MRT consisted of Caller A reading from a pre-selected word list and Caller B recording what is heard on a multiple choice answer sheet. Subsequently, Caller B read from a pre-selected word list while Caller A recorded the words on the multiple choice answer sheet. The word list used for the MRT is given in Appendix A. Three samples were taken of each test scenario. In order to establish a baseline for evaluating voice intelligibility on the Iridium phones, the same procedure was repeated for all word lists for a call between two PSTN devices. It was considered that intelligibility over the PSTN was close to 100%. In the case where francophone speakers were testing the voice intelligibility over the Iridium satellite phones, a random letter/number test sequence was used. Caller A recorded and read a random sequence of 10 numbers and letters. Caller B recorded what they heard. The same procedure was repeated in the opposite direction with Caller B reading a random sequence of letters and numbers. Again, three samples were taken for each test scenario using francophone speakers.

3.3 Test Scenarios

The different combinations of devices used to evaluate the Iridium voice service over different communications links are given in Table 1. During the evaluation period, the voice service used combinations of Iridium, PSTN, and digital cell phone devices. All combinations of male and female speakers in both English and French were evaluated.

Table 1 Combinations Used for the Evaluation of the Iridium Voice Service

Language	Speaker		Listener	
	Gender	**Device**	**Gender**	**Device**
English French	Male Female	Iridium PSTN Digital cell Speaker phone Cordless	Male Female	Iridium PSTN Digital cell Speaker phone Cordless

The majority of the tests were carried out on site at DREO. The Iridium phones were used outside in order to get a clear view of the sky. The digital cell phone was used both inside a building and outside.

4 RESULTS AND OBSERVATIONS

4.1 Call Statistics

A summary of the call statistics over the evaluation period is given in Table 2. Almost 50 calls were recorded during the evaluation period. The length of calls ranged from 4 seconds to just over 22 minutes. Of those calls, approximately 70% were dropped, with an average drop time of 4 minutes 15 seconds. On average, it took about 20 seconds for the call to be established, with the time being measured from when the "OK" button was pressed to initiate dialing to when the call is answered. On numerous occasions, a "system busy" signal would be received when trying to place a call.

Table 2 Summary of Call Statistics

Parameter	Minimum	Maximum	Average
Number of calls	46+	-	-
Call setup latency	8 s	47 s	21.3 s
Calls dropped	33	-	-
Call drop time	2 s	18 m 16 s	4 m 15 s
Call duration	4s	22 m 8 s	-

As a baseline test, the MRT was carried out over the PSTN. Each of the nine word lists from the MRT was read. The result of the baseline test was that 96% of the words were understood correctly. During the evaluation of the Iridium voice service, the individual abbreviated MRT (English language) achieved 74% to 97% intelligibility scores, communication between Iridium and digital cellular service being the worst. Using the random number/letter sequences (French language), individual scores ranging from 70% to 97% were achieved, communication between Iridium and digital cellular service being the worst. The average scores for the various classes of test are given in Table 3 using the abbreviated MRT test. The individual test scores are given in Appendix B.

Table 3 Error Statistics

Call type	Total errors	Total words	Intelligibility
Baseline, PSTN only	28	740	96%
PSTN / Iridium	74	480	86%
Iridium / Iridium	37	240	85%
Iridium / Cellular (digital)	121	460	74%
English language	232	1180	80%
French language	95	600	84%
Male speaker	154	900	83%
Female speaker	173	880	80%
Total	327	1780	82%

4.2 Observations

Subjective observations

In general, users noted that speech was garbled especially in cases where there were longer periods of silence. This may be due to a vocoder startup problem and may be the cause of the difference between intelligibility tests done in English and French. The time between words was longer in the MRT test to allow the listener to mark which word they thought they had heard. The Iridium system is voice activated in that a signal is only transmitted when its strength exceeds a certain threshold. As a result, when there are periods of silence, the vocoder must be re-initialized each time speech recommences or the threshold of the signal level is exceeded. Conversely, users commented that wind noise was easily picked up by the microphone and caused some degradation in speech intelligibility. Other comments included that speech was slurred or that the call was hollow sounding. There was a noticeable delay in the speech as users were often caught talking over one another, thereby requiring the speaker to repeat what he/she said. Once users become more experienced with using the Iridium phone, the problem of talking over one another diminished. Occasionally, users would experience intermittent drop outs or fading of the voice. The occurrence of such anomalies seem to correspond to when satellite handover was expected to take place.

System busy – resolution by re-registering or turning phone off and on

Users reported that when calls could not be connected a "System busy" message would appear on the display of the phone. However, the problem was often resolved simply by turning the phone off and back on again, or by re-registering the phone on the Iridium system. This may be caused by a poor orientation of the satellite constellation. Further testing using an orbit simulator would be required to confirm this hypothesis.

Display of duration of call – too short

For the evaluation of the Iridium voice service, the duration of calls made was an important parameter to be monitored. It was found that although the duration of the call was available from the display, it was difficult to capture the information, as it would only remain displayed for a couple of seconds. Since it was sometimes difficult to determine when a call was terminated, a user did not have time to look at the display to record the duration before it disappeared.

Call drop out average – correspond to satellite handover?

As listed in Table 2, the average call drop time was found to be 4 minutes and 15 seconds. It is noted that the average satellite handover interval is approximately 5 minutes which could account for the results obtained. In addition, prior to the call being dropped, users observed intermittent fading in and out of the signal. As above, further testing to determine the cause of this problem will require an orbit simulator to be used with the testing.

Weak signal message – still able to put call through

When a user first turns the phone on to register onto the Iridium network, an indication of the signal strength is displayed. During the evaluation, a "weak signal" indicator appeared on the display on several occasions. However, despite the indicator, calls were successfully connected. This unexpected observation raises some question as to what is considered a weak signal and whether it should have an impact on the ability to make calls or not.

Long distance charges to access message centre outside North America

During one particular test, there was a requirement to change a user option setting for the phone. One simple way of accomplishing this was to phone the message centre and to change the options manually. It was discovered that long distance charges are incurred when dialing to the message centre from outside North America. Thus, if a user received notification of a voice message, they would have to incur long distance charges to retrieve the message.

MRT correlation

As mentioned in Section 4.1, results between 74% and 97% were achieved for the abbreviated MRT. An analysis of the data showed common errors in the wordlists occurred between (path ↔ pass), (bass ↔ bath), (pot ↔ hot), (dung ↔ dun), (sung ↔ sun), (seem ↔ seen), (lame ↔ lane), (seep ↔ seek), (day → pay), (sub ↔ sud). Table 4 contains a list of words that were often received in error, but where the mistaken word was variable.

Table 4 MRT Words Received in Error

MRT Word	Mistaken for
sit	bit, fit hit
din	pin, win, fin
kit	sit, hit
say	pay, day
sin	pin, fin
dig	fig, pig
sold	gold, cold, told
dent	bent, tent
fin	tin, pin, win

Iridium to Digital cell performance

The results of the evaluation showed that speech intelligibility was worse when the communications link was established between an Iridium phone and a digital cell phone. The reduced performance of this link may be due to incompatibility of the vocoders in the Iridium phone and in the digital cell phone.

Performance with Female Speaker

In general, performance of the speech intelligibility over the Iridium was found to be worse with a female speaker, 80% versus 83% for a male speaker. A possible reason for this result may be due to the vocoder being optimized to encode the range of frequencies for a male voice. As the female voice is usually slightly higher than a male voice, the reproduction of the signal at the receive end may not be as accurate. It is not known whether the vocoder in the Iridium phone is optimized for a particular range of frequencies.

Issues Outstanding

Although it is suspected that "System busy" and the dropped calls are related to satellite orbit and handover, it would be beneficial to verify whether this is the case. A simulation package called Satellite Tool Kit (STK) from Analytical Graphics Inc, is available in which the Iridium constellation can be modeled. By providing updated ephemeris data to the simulation for a given date and time, the Iridium satellites can be tracked for a particular location (latitude and longitude). Consequently, additional voice service tests can be carried out while running the STK to see if "System busy" is the result of poor orientation of the constellation orbit and whether satellite handover is noticeable by the user in terms of voice intelligibility and dropped calls.

As described in Section 2, satellite messaging is a feature of the Iridium phone. While some users have been able to successfully send text messages, others have not received messages sent to the phone. It is thought that the problem is related to the user options settings for the phone and pager if "Follow me paging" has been activated. Further testing of satellite messaging is planned in the near future.

5 CONCLUSIONS

5.1 General Comments

The Iridium voice service was evaluated under a number of conditions, between both male and female speakers in English and French, and to a number of different devices. The users were always aware that a vocoder was being used. However, after some experience using the system, and under good conditions, speaker recognition was possible. Understanding ranged from near PSTN quality to poor, with an acceptable rating for most of the calls. The average 4 minutes of usable conversation times would probably be acceptable for most applications. The greatest success was obtained when the Iridium phones were used away from buildings or other obstructions. The most acceptable calls were between two Iridium phones or between Iridium and PSTN phones. Calls made to terrestrial cellular phones were of lower voice quality and connections were less reliable.

The user acceptance and ease of use of the system would probably depend on past experience of the user and perceived expectation from the Iridium system. If the user expects a terrestrial cellular equivalent, there will be a disappointment in terms of where the system can be used (i.e. inside buildings), quality of the voice, and call length. However, if the user considers the system as a replacement of terrestrial HF, a replacement of current SatCom service, or a new service were none now exists (i.e. polar and remote locations), the Iridium system is a large step forward.

5.2 Recommendations for Further Testing

This work identified two areas where the use of an orbit simulator with the test could pinpoint possible problem areas such as, "System Busy" and calls being dropped. Data service was not tested, as this service was not available. This will be tested when available. Director Air Requirements (DAR), in cooperation with DREO are performing tests to Arctic locations and aircraft mounted Iridium phones. They results of these tests will be reported when complete.

6 REFERENCES

[1] www.iridium.com
[2] www.flatoday.com
[3] www.infosat.com
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[5] Motorola Iridium 9500 Portable Phone User's Guide, 1998

Appendix A Word List for MRT

DREO Iridium Satellite Phone Voice Service/Intelligibility Test

1	went dent	sent tent	bent rent	**11**	dug dud	dung dub	duck dun
2	hold fold	cold sold	told gold	**12**	sum sup	sun sub	sung sud
3	pat path	pad pack	pan pass	**13**	seep seek	seen seem	seethe seed
4	lane lake	lay lace	light lame	**14**	not pot	tot hot	got lot
5	kit hit	bit wit	f it sit	**15**	vest best	test west	rest nest
6	must rust	bust dust	gust just	**16**	pig pip	pill pit	pin pick
7	teak teach	team tear	teal tease	**17**	back bass	bath bat	bad ban
8	din dig	dill dip	dim did	**18**	way pay	may day	say gay
9	bed red	led wed	fed shed	**19**	pig wig	big rig	dig fig
10	pin fin	sin din	tin win	**20**	pale pane	pace pay	page pave

\# Right: ____________
\# Wrong: ____________

Appendix B Individual Test Scores

Test	Date	Scenario	Sample, correct/total			Score		
			1	2	3	errors	total words	%
1	29/04/99	EMPMP				6	180	96.67%
2	29/04/99	EFPMP				9	180	95.00%
3	29/04/99	EMPFP				7	180	96.11%
4	29/04/99	EFPFP				6	200	97.00%
Average for English, PSTN - PSTN						28	740	96.22%
5	29/04/99	EMIMP	14/20	14/20	18/20	14	60	76.67%
6	29/04/99	EMPMI	18/20	19/20	17/20	6	60	90.00%
7	29/04/99	EMPFI	19/20	18/20	19/20	4	60	93.33%
8	29/04/99	EFIMP	18/20	16/20	19/20	7	60	88.33%
9	18/05/99	EFPMI	16/20	16/20	14/20	14	60	76.67%
10	18/05/99	EMIFP	19/20	18/20	18/20	5	60	91.67%
11	18/05/99	EFPFI	16/20	15/20	16/20	13	60	78.33%
12	18/05/99	EFIFP	17/20	13/20	19/20	11	60	81.67%
Average for English, PSTN - Iridium						74	480	84.58%
13	20/05/99	EMDMI	17/20	19/20	15/20	9	60	85.00%
14	20/05/99	EMIMD	14/20	19/20	12/20	15	60	75.00%
15	20/05/99	EFDMI	19/20	15/20	16/20	10	60	83.33%
16	20/05/99	EMIFD	12/20	14/20	15/20	19	60	68.33%
17	20/05/99	EFDFI	16/20	10/20	15/20	19	60	68.33%
18	20/05/99	EFIFD	13/20	?	17/20	10	40	75.00%
19	20/05/99	EMDFI	14/20	11/20	12/20	23	60	61.67%
20	20/05/99	EFIMD	14/20	15/20	15/20	16	60	73.33%
Average for English, Digital Cellular - Iridium						121	460	73.70%
21	20/05/99	EMIMI	17/20	20/20	18/20	5	60	91.67%
22	20/05/99	EFIMI	17/20	15/20	15/20	13	60	78.33%
23	20/05/99	EMIFI	17/20	18/20	16/20	9	60	85.00%
24	20/05/99	EFIFI	15/20	18/20	17/20	10	60	83.33%
Average for English, Iridium - Iridium						37	240	84.58%
Average for English						232	1180	80.34%
25	18/05/99	FMPMI	7/10.	9/10.	8/10.	6	30	80.00%
26	18/05/99	FMIMP	8/10.	10/10.	8/10.	4	30	86.67%
27	18/05/99	FFPMI	10/10.	7/10.	7/10.	6	30	80.00%
28	18/05/99	FMIFP	10/10.	8/10.	8/10.	4	30	86.67%
29	18/05/99	FFPFI	9/10.	8/10.	9/10.	4	30	86.67%
30	18/05/99	FFIFP	10/10.	10/10.	9/10.	1	30	96.67%
31	18/05/99	FMPFI	9/10.	9/10.	10/10.	2	30	93.33%
32	18/05/99	FFIMP	10/10.	8/10.	9/10.	3	30	90.00%
Average for French, PSTN - Iridium						30	240	87.50%

32	18/05/99	FMDMI	8/10.	8/10.	9/10.	5	30	83.33%
33	18/05/99	FMIMD	7/10.	9/10.	8/10.	6	30	80.00%
34	18/05/99	FFDMI	6/10.	7/10.	8/10.	9	30	70.00%
35	18/05/99	FMIFD	8/10.	7/10.	9/10.	6	30	80.00%
36	18/05/99	FFDFI	7/10.	9/10.	9/10.	5	30	83.33%
37	18/05/99	FFIFD	8/10.	8/10.	8/10.	6	30	80.00%
38	18/05/99	FMDFI	7/10.	10/10.	10/10.	3	30	90.00%
39	18/05/99	FFIMD	7/10.	6/10.	9/10.	8	30	73.33%
Average for French, Digital Cellular - Iridium						48	240	80.00%
40	18/05/99	FMIMI	8/10.	9/10.	9/10.	4	30	86.67%
41	18/05/99	FFIMI	8/10.	8/10.	8/10.	6	30	80.00%
42	18/05/99	FMIFI	10/10.	8/10.	7/10.	5	30	83.33%
43	18/05/99	FFIFI	10/10.	10/10.	8/10.	2	30	93.33%
Average for French, Iridium - Iridium						17	120	85.83%
Average for French, Iridium - Iridium						95	600	84.17%
Average not including PSTN - PSTN						327	1780	81.63%
Average, male to male						74	450	83.56%
Average, female to female						81	430	81.16%
Average, male to female						80	450	82.22%
Average, female to male						92	450	79.56%

Code for Scenario column

Language	Speaker Gender	Speaker Phone	Listener Gender	Listener Phone
English = E French = F	Male = M Female = F	PSTN = P Iridium = I Cellular = D	Male = M Female = F	PSTN = P Iridium = I Cellular = D

Example, EFIMD = English language, female speaker on an Iridium phone, male listener on a cellular phone.

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The Iridium system is designed to provide global personal communications via an interconnected constellation of Low Earth Orbit (LEO) satellites communicating directly with handheld terminals. The system provides communications to all parts of the globe, including the polar regions. This document describes the DREO evaluation of the Iridium voice service under a number of different scenarios. Also included is an overview of the general features and operation of the satellite phone.

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